HNOLOGY DEPARTMENT

First Copy

Vol. X. No. 15. NOVEMBER, 1947

THE ENGLISH ELECTRIC JOURNAL

PUBLIC LIBRARY
JAN 6 - 1948
DETROIT

CONTENTS.

	PAGE
Gear Tooth Loading of Axle Suspended Electric Traction Motors	306
Removal of Generator Rotor Shafts by Combined Shrinkage and Expansion	311
Electricity and the Brickmaking Industry	314
Underground Rectifier Substations for 11,000 volt Supply	319
The Napier "Naiad" Aero Engine	324
Llynfi Power Station, South Wales	325

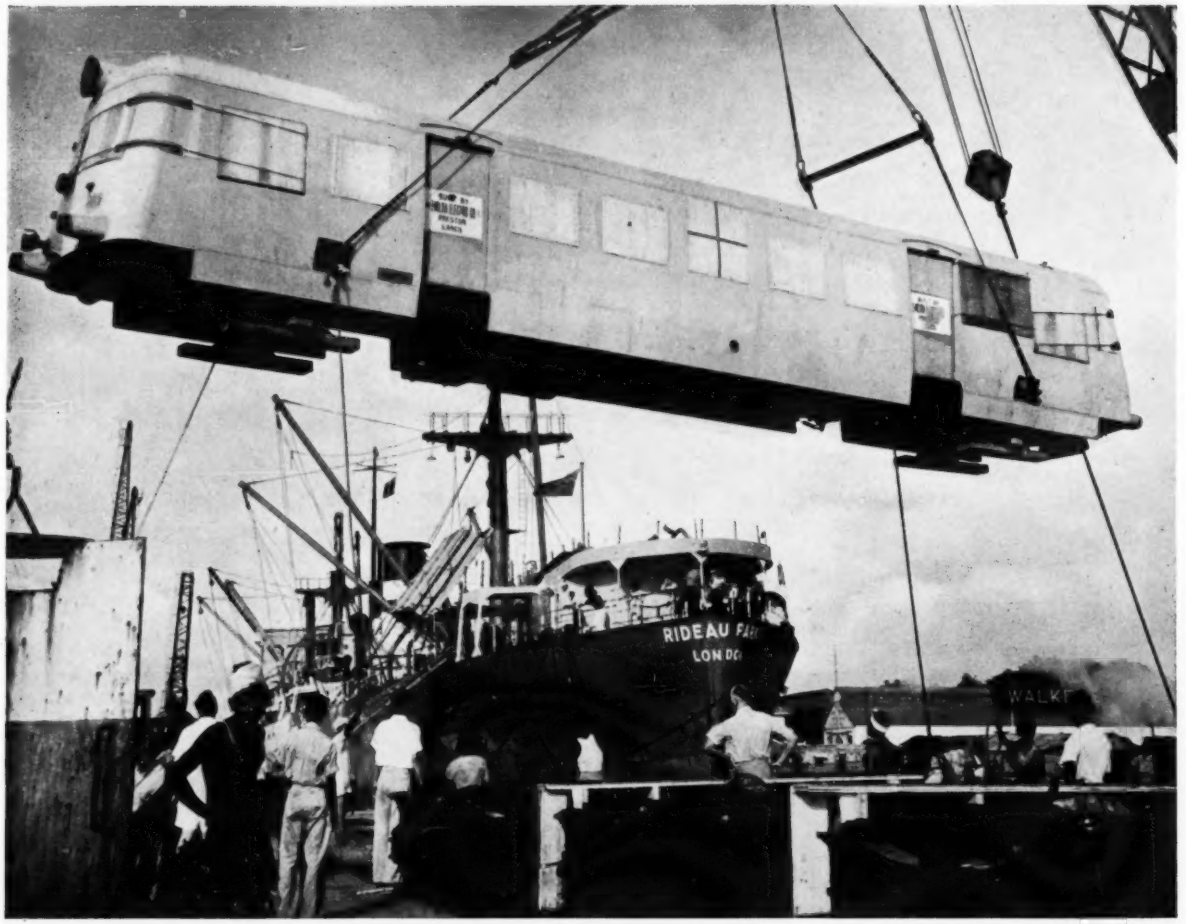
All Communications respecting Editorial Contents should be addressed to The Editor, The English Electric Journal, The English Electric Company Limited, Stafford.

All rights of republication, including translation of articles, are reserved.

Published by

THE ENGLISH ELECTRIC COMPANY LIMITED

STAFFORD



Unloading one of the 23 diesel-electric railcars being made by The English Electric Company for The Ceylon Government Railways. These cars can operate either as single units or as multiple-unit trains.

The English Electric Journal

Vol X. No. 15 NOVEMBER, 1947. One Shilling

Gear Tooth Loading of Axle-Suspended Electric Traction Motors.

By E. A. BINNEY, Chief Engineer, Traction Machine Development Department, Bradford.

Axle-suspended traction motors are in general use in tram, motor coach and many locomotive drives. In most cases the gear drives are single reduction, there being a pinion secured to an extension of the armature shaft and a gear wheel mounted on the wheel axle. In some special applications, a double-reduction drive is provided, an intermediate shaft carrying the gear wheel of the first gear train and the pinion of the second gear train. The bearings for this shaft are supported on the motor frame.

The correct gear centre for the gear wheel mounted on the axle and the corresponding pinion is ensured by providing axle suspension bearings on one side of the motor frame. The axis of these bearings is accurately spaced relative to the armature shaft so as to provide the correct gear centres when the motor frame is mounted on the axle. The other side of the motor is usually supported on a bracket extending from the bogie transom, usually on a rubber block intended to provide a certain degree of resilience and allow for some movement of the motor frame relative to the bogie transom.

Fig. 1 illustrates a diagrammatic plan view of an axle-suspended motor with single reduction gear drive, and shows that in effect the mounting provides a three-point support, comprising the two suspension bearings and the frame nose. This method of support is commonly used on motor coach and locomotive drives and is of chief interest in the matter under consideration.

In Fig. 1, the relative position of the gear tooth load and centre of gravity of the motor are indicated by P and G respectively, it being borne in mind that the gear load is upward for one direction of rotation and downward for the other rotation, assuming motoring load. It is obvious that a gear force in a downward direction will produce a reaction on the motor shaft in an upward direction, and vice-versa.

The upwardly directed force results in a moment around the axis NS1, extending from the motor nose to the suspension bearing remote from the gear, while the moment of the opposite force acts around the axis NS2, from the nose to the near suspension bearing. In both cases the moment is opposed by the moment formed by weight of the motor and the corresponding radii, l_1 and l_2.

The condition of equilibrium is reached when the opposing moments are equal,

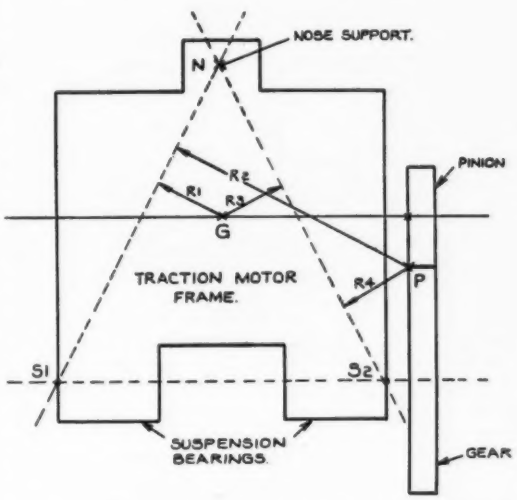


Fig. 1.—Diagrammatic plan view of an axle-suspended motor with single-reduction gear drive.

i.e., $P\ l_2 = G\ l_1$ for downward tooth load.
$P\ l_4 = G\ l_3$ for upward tooth load.

When the value of P increases beyond the values established from the above equations, the motor frame will be tilted around the corresponding axis to the extent permitted by the clearance in the suspension bearings.

A very interesting fact is brought out in considering the condition of equilibrium for the two rotations. In the case of upward movement of the frame, the gear pressure P required to give equilibrium is small as compared with the weight G. In the opposite direction the values P and G are of about the same order. It follows that when the pinion rotates in a direction exerting a downward pressure on the gear wheel, a relatively light gear load will produce the necessary moment to overcome the motor weight. In actual practice this tilting action may take place under practically all load conditions, except of course the " off power " condition.

On the other hand, in the reverse direction of rotation, the gear load must, clearly, be fairly high and may in some unusual cases never be sufficient to overcome the opposing moment due to the motor weight. This may occur in the case of the older type of axle-suspended motors, especially the totally-enclosed machines. However, even in these cases the motor usually is tilted downwardly during acceleration of the train, as the peak tooth loads are sufficient to produce this result.

It should be mentioned that there is an additional tilting of the armature in its frame, the bearing clearance allowing the armature to be tilted upwardly from the pinion end in one direction and downwardly in the other direction of tooth loading.

The effect of these armature and frame movements relative to the axle, is to move the armature shaft out of parallel with the axle, thus inclining the pinion teeth relative to the gear teeth, the out of alignment angle being more or less proportional to the bearing clearance and inversely to their axial spacing. The angle will vary from about 3 mins. to 10 mins. according to the conditions mentioned. Obviously in one and the same motor the angle will vary if the bearing clearances increase due to normal wear. In the case of sleeve-type bearings this clearance increase is quite appreciable. A common variation of suspension bearing clearance encountered in practice is from .01 in. when new to .03 in. or over when well worn, that is, approaching the replacement condition.

The result of this out of parallelism of the intermeshing gears is that the heavy gear loads are always imposed on the end of the teeth nearest the motor frame, assuming, of course, that the teeth are accurately machined. In the case of new gears and pinions, this condition can readily be noted after a short period of running. The appearance after a more prolonged period, however, depends entirely upon the type of gears and pinions used.

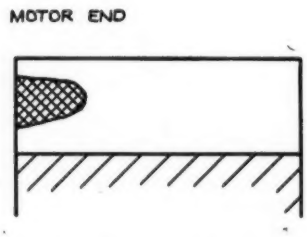


Fig. 2.—Pinion tooth wear with downward pressure.

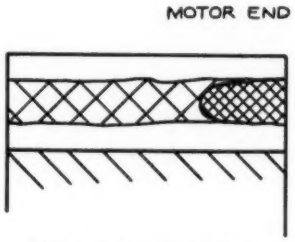


Fig. 2a.—Pinion tooth wear with upward pressure.

The majority of traction gears fall in one of the three following categories :—

(1) Case-hardened—ground or unground. Brinell hardness 600 plus.
(2) .4—.5 carbon or equivalent alloy. Brinell hardness 450.
(3) Prehardened alloy steel 60-65 tons U.T.S. Brinell hardness 270-300.

The case-hardened gears soon develop a highly-polished area at the tooth ends nearest the motor, especially the pinion teeth, this area assuming a more or less triangular shape, as shown in Fig. 2 with the base formed by the motor end of the tooth. This characteristic is more pronounced on the pinion tooth flank exerting a downward thrust. The opposite flank usually shows a fainter polish over the full tooth flank extending from the highly-polished end area, as shown in Fig. 2a. The reason for this difference in marking is as explained previously, that in one direction of rotation, the axes are out of parallel on nearly all loads while in the other direction of rotation the lighter loads are carried on the full tooth length, only the heavier loads, such as the accelerating load, being sufficient to tilt the motor frame and hence the armature shaft relative to the wheel axle.

Due to the extremely hard surface of the case-hardened gears, the rate of wear, even with the highly concentrated load, is very slight.

Hence, even under the extremely adverse operating conditions resulting in very localised abrasive action, an appreciable bedding in of the gear teeth cannot be expected over a considerable number of years because the out of alignment increases at a much greater rate owing to the suspension bearing wear, assuming these to be of the conventional sleeve type.

Where the gear and pinion teeth are accurately ground the area of high-pressure loading is very readily seen, as on one tooth flank the original grinding marks will frequently be found to extend over $\frac{1}{2}$ to $\frac{3}{4}$ the tooth flank even after several years of service. These grinding marks are, of course, on the outer end portion of the teeth, i.e., the part remote from the motor.

In some cases, due to inaccuracy of grinding, machining tolerances in the motor frame, etc., the polished area may be found at the outer end of the tooth flank, only. This is, however, unusual and of no particular significance.

In the case of the second class of gear referred to, the rate of wear will normally be greater and an extension of the worn surface will take place on the pinion considerably more rapidly than experienced with the case-hardened gears.

With pre-hardened gears of the third class referred to, the usual practice is to use a hard-surface pinion of the first or second category. The wear in this case will show up on the gear teeth. Initially this is frequently in the form of pitting on the tooth flank portion nearest the motor. This pitting eventually is replaced by a gradually widening area of contact which results in a tapering of the teeth, that is, when measured, the tooth thickness is found to be least at the motor end, and greatest at the remote end. This wear takes place at a very much greater rate than with the case-hardened type of gear, the taper in a sense adapting itself to the changing angle of the shafts with increasing suspension bearing clearance. Thus, when the worn bearings are replaced by new ones with reduced clearance the bedding-in process must start afresh, with the result that a rather complex tooth shape may result before the gear wheel is discarded.

Case-hardened ground gear wheels have an extraordinary resistance to wear, and in consequence the tapering of the gear wheel tooth is extremely slight. The pinion teeth will wear at a much greater rate than the gear wheel teeth, but even so, measurements taken have indicated an annual rate of wear of perhaps .002 in. only at the motor end and much less at the centre of the tooth.

It will naturally be deduced that this is a very satisfactory state of affairs and quite rightly. There are many equipments which have operated on motor coaches for over a million miles without gear replacements being required due to wear.

The question of excessive back lash hardly arises when case-hardened gears are in use, this being mainly affected by change in gear centres due to bearing clearance rather than tooth wear. With accurately ground gears backlash can be held to a minimum value with the result that the gear noise is reduced to a minimum.

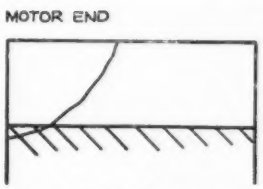


Fig. 3.—Critical stress line for straight flank tooth.

One rather important factor, however, comes to the front in the use of case-hardened gears which is of less importance in other types, namely, the possibility of tooth failure due to fatigue stress. The localizing of the heavy load at the end of the tooth greatly increases the bending stress. Fig. 3 shows the direction of the critical stress line for an end-loaded tooth, and the probable location of fatigue failure. The end nearest the motor usually fails. Fig. 4 illustrates a very bad case of fatigue failure. Usually, of course, a failure is detected before it has progressed to such an extent.

Fig.4a shows a traction motor pinion in which failure has occurred in the form of severe chipping, the motor end of the teeth having worn down in a very pronounced manner as can be seen in the tapering of the tooth crown. The circumferential groove in the teeth is at the outer end.

In order to avoid end-loading of case-hardened gears, it is necessary either to eliminate the angularity of the shafts under load or move the centre of pressure towards the centre of the gears.

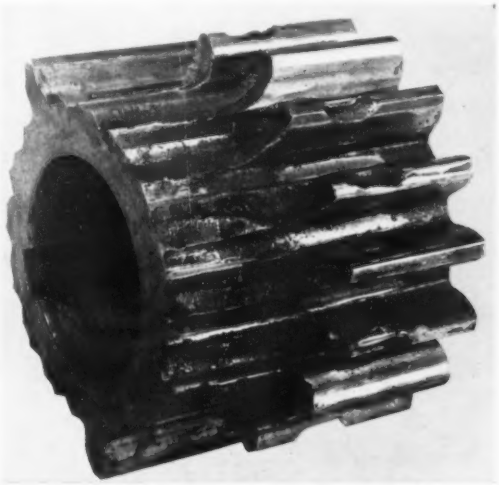


Fig. 4.—Fatigue failure of traction motor pinion.

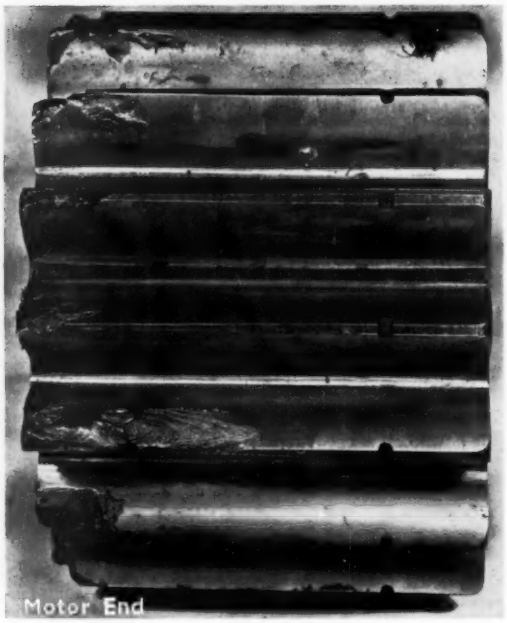


Fig. 1a.—Severe chipping of traction motor pinion teeth due to fatigue failure.

Angularity depends on the armature and suspension bearing clearances and even with the use of roller bearings in both positions there will, of course, be a certain minimum clearance which is sufficient to cause tooth end loading. However, the radial wear of roller bearings is very slight. Hence, once the bedding-in has progressed to a sufficient extent, the heavy loads will be carried on an appreciably greater length of the tooth flank. Nevertheless, the condition still exists that tilting of the armature axis relative to the wheel axle occurs only under the heavier loads in one rotation, while in the other rotation it may occur under a much wider range of load. Consequently, the tooth surface will not acquire an angle suitable for complete load distribution under all load conditions.

One solution is to provide two gear trains, one on either end of the motor, and with equal loading the tilting action will be avoided. This arrangement is used in Europe, the gears having opposed helical teeth which assists in sharing the load evenly.

As the practice in England is to use a single gear train, the problem

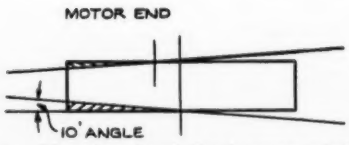


Fig. 5.—Plan view of tooth showing taper grinding. Shaded area is metal removed.

can best be solved by initially providing a taper on the pinion teeth from the motor end, running out at or near the centre of the tooth flank as shown in Fig. 5. The angle of the taper can be made just sufficient to ensure that under the worst conditions, i.e., maximum bearing clearance, the pressure is carried on an area away from the end of the tooth. In practice this angle is of the order of only 10 mins., i.e., it is a very small angle. This factor is of importance as it has influence on the manner in which the tapering is carried out.

Consider a gear of 5 in. face width and assume that the taper runs out at the centre, i.e., $2\frac{1}{2}$ in. from the motor end of the tooth, the amount removed from a normally straight tooth will be—

$$d = 2.5 \text{ tg } 10 \text{ min.} = .007 \text{ in.}$$

In the case of a tooth which has been ground after case hardening, the case depth remaining will be at least .07 in. deep, so that at the worst, the amount removed is only 10 per cent. However, the case depth at the centre, i.e., where the taper runs out, is the original depth.

As the whole object of tapering the tooth is to locate the centre of pressure on the area where the taper runs out, it is obvious that the removal of material in this manner will in no way impair the life of the gear as far as wear is concerned.

It can also be readily seen that an extension of the taper beyond the centre will serve no

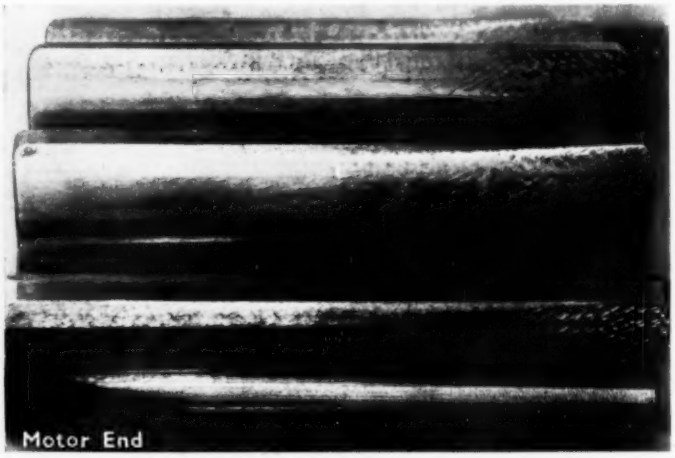


Fig. 6.—Pinion tooth flank of a straight (untapered) tooth after about 200,000 miles operation.

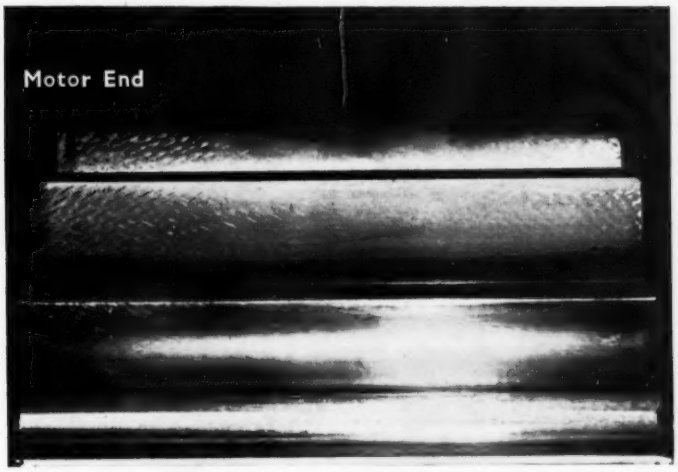


Fig. 7.—Pinion tooth flank of a tapered tooth after about 200,000 miles operation.

useful purpose while at the same time the amount of case removed at the end is proportionately greater. Again, no purpose is served in increasing the angle, the disadvantages being obvious.

Figs. 6 and 7 show the appearance of a pinion tooth flank of a straight (untapered) tooth and a tapered tooth respectively after a period of about 100,000 miles operation. In both cases the flank shown corresponds to the rotation resulting in the maximum operation with tilted shaft. It should be mentioned that the signs of wear on the mating gear wheel teeth is very much less, since the gear ratio is usually between 3 and 4 to 1.

Fig. 4a illustrates very forcibly the tapering wear which has gradually developed during the life of the pinion. This wear clearly resulted in the ultimate chipping of the teeth, this commencing at the extreme motor end. The outer end portions of the teeth are only slightly worn. Had the teeth initially been tapered, the load would have been less concentrated and the pinion life increased.

Tapering of the pinion teeth is undoubtedly an expedient which at first glance appears to be contrary to correct principles. However, the incontestable fact remains that by this very simple means the problem of relieving the end of the tooth from the heavy loads is achieved. At the same time there will be a considerable increase in the effective pressure area which will reduce the tooth wear. This can be readily understood by consideration of Figs. 8a and 8b, which show the probable distribution of pressure on the contacting teeth flanks under heavy load for the straight teeth and tapered teeth (exaggerated), respectively, it being assumed that the lubricant will cause a certain degree of pressure distribution in a longitudinal sense. If this assumption is correct, it follows that the effective pressure area is very much greater in the case of the tapered teeth.

There are, of course, other factors which introduce angularity between gear wheel and pinion teeth. It is commonly believed that shaft flexure is mainly responsible for end loading. Also there is the twisting of the pinion teeth due to torsional stress. While under the normal load conditions neither of these factors introduce angularity of the order due to tilting of the frame, they do add to the angularity, and tapering of the pinion is again the remedy against end loading from these causes.

Manufacturing tolerances are held very close on ground teeth. However, with the unground hardened-surface gears the distortion which occurs in the hardening process introduces angularity of varying degrees which may in some cases cause a displacement of the load towards the centre. Coning of the gear rim for instance, has this effect to a slight degree. Tapering of the teeth of pinions meshing with distorted gear teeth will, in most cases be helpful, but to a varying extent.

Finally, it should be mentioned that the taper grinding in no practical degree alters the true involute tooth form.

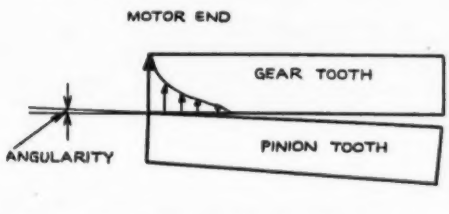


Fig. 8.—Tooth pressure distribution with straight flanks.

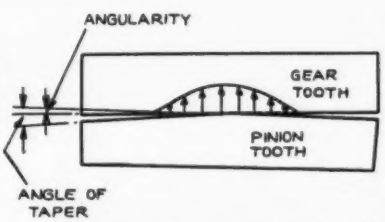


Fig. 8a.—Tooth pressure distribution with tapered pinion flank.

Removal of Generator Rotor Shafts by Combined Shrinkage and Expansion.

By T. ECCLES, M.I.P.E., New Development and Process Section, Stafford Works.

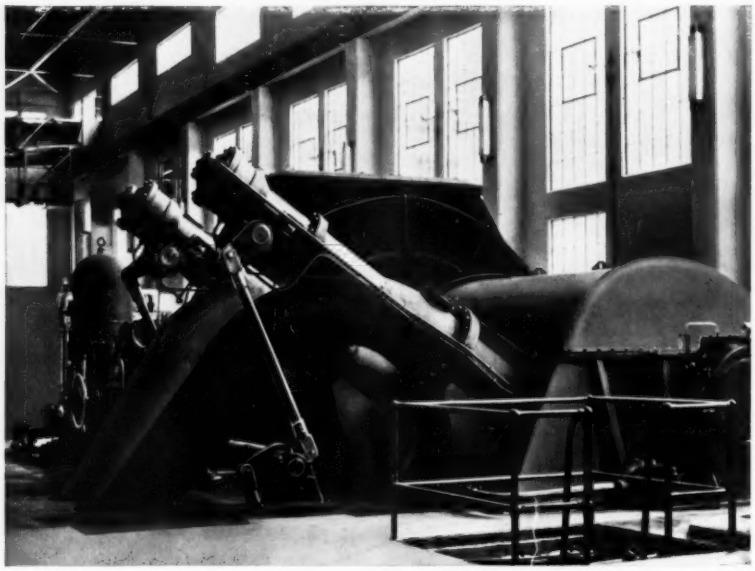


Fig. 1.—One of the 21,000 H.P. water turbine-driven Alternator Sets installed at the Tarraleah Power Station of the Tasmanian Hydro-electric Commission.

During the course of manufacture by this Company of two 21,000 H.P. horizontal-impulse water turbine-driven generating sets for Tasmania, the alternating current generators had to be fully erected and tested at the Stafford Works. For shipping purposes, however, it was necessary to remove the shafts from the rotors after the completion of the tests, and the following is a description of the method employed to do this.

Fig. 1 shows one of the complete sets now in operation on site. The rotor assembly is shown diagramatically in Fig. 2, the laminated body being in two parts with two stepped fits on the shaft which has a 4 in. diameter hole throughout its length.

For shrinking the rotor body on to the shaft during the original assembly, the body only was heated by 12 kW electric elements placed in the dovetail slots around its circumference, the total electrical load used for this purpose being 132 kW. After heating by this means for 30 hours the temperature of the outside was 257° C., and of the inside 200° C., and the bore had expanded sufficiently to allow the shaft to be lowered into position.

Clearly the removal of the shaft for shipment presented a more complicated problem. The rotor body had been shrunk on with an allowance of .018 in. interference fit, and this intimate contact between body and shaft would naturally encourage the transfer of heat from one to the other, tending to defeat any attempt to expand the bore without also expanding the shaft, especially as the materials of both had similar thermal conductivity. Gradual heating of the rotor body would be quite useless unaccompanied by other measures to control the shaft temperature. Furthermore, when metallic surfaces have been in intimate contact for some time there is a tendency for them to adhere to each other.

An important point which may be overlooked when considering this problem is the fact that if a sufficient amount of heat is applied to the outside of the rotor, the tendency is to draw the bore of the rotor outwards, especially if the heat can be applied quickly in order to minimise its transfer towards the bore. Similarly, cold applied to the centre of the shaft tends to draw the outside of the shaft towards the centre. The desired result can thus be obtained even if the

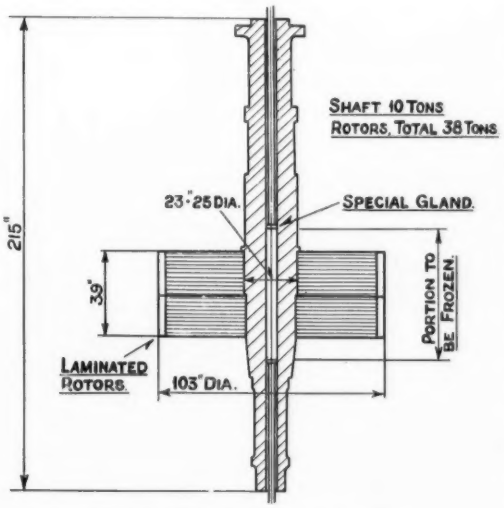


Fig. 2.—Diagrammatic section of rotor.

temperature of shaft and rotor bore is the same.

It was decided to apply this principle, using the 4 in. diameter axial hole in the shaft for cooling, but in order to prove that it would be successful a dummy test shaft was made, long enough to protrude about 1 ft. at each side of one rotor packet. An actual rotor packet was used but it was bored to a diameter slightly less than the final size so that any minor damage to the bore which might occur during the test would not be detrimental to the finished machine. The shaft was machined to give .018 in. interference fit.

It was estimated that refrigeration plant would be required capable of cooling 1,400 gallons of calcium chloride brine per hour to 17-20° F. with a total extraction of 87,000 B.Th.U. per hour; that the driving motor for the circulating pump would be 15 H.P., and that the total cost of orthodox plant would be about £750. Calculations showed that this plant would maintain the surface temperature of the shaft bore at approximately 80° F. (26.9° C.), and that the outer surface of the rotor would have to be heated to approximately 280° F. (138° C.). The general usefulness of such plant had, however, to be considered, and as the number of shafts likely to be removed by this process would not justify its purchase, some other means of cooling had to be devised.

The decision was therefore made to adopt the arrangement shown in Fig. 3, in which calcium chloride brine of 1.2 density was to be used as the cooling medium to be circulated from a tank through the hollow shaft and back to the tank for cooling. The brine was to be cooled in the tank by solid CO_2 supplied under the trade name of "Drikold," by Imperial Chemical Industries, Ltd. The temperature of "Drikold" is minus 110° F. (minus 79° C.). The freezing point of calcium chloride at a specific gravity of 1.2 is minus 12.5° F. (minus 25° C.).

A special tank was prepared to the sketch reproduced in Fig. 4. Its dimensions were 5 ft. × 5 ft. × 4 ft. deep and it was thermally insulated with granulated cork held in position by an outer wooden box. A copper lid was provided having eight cylindrical pockets immersed in the brine and extending nearly to the bottom of the tank. It was intended to charge each pocket with bricks of Drikold but in actual operation it was found more effective and economical to insert the Drikold straight into the brine. The copper lid and pockets were therefore dispensed with and the tank was covered with an asbestos blanket as thermal insulation and to contain the fumes. The "Drikold," handled with leather gloves, was broken up into small pieces and dropped into the tank by folding back the asbestos blanket. As indicated in Fig. 3, the brine was circulated from the bottom of the tank, upwards through the shaft and back to the tank,

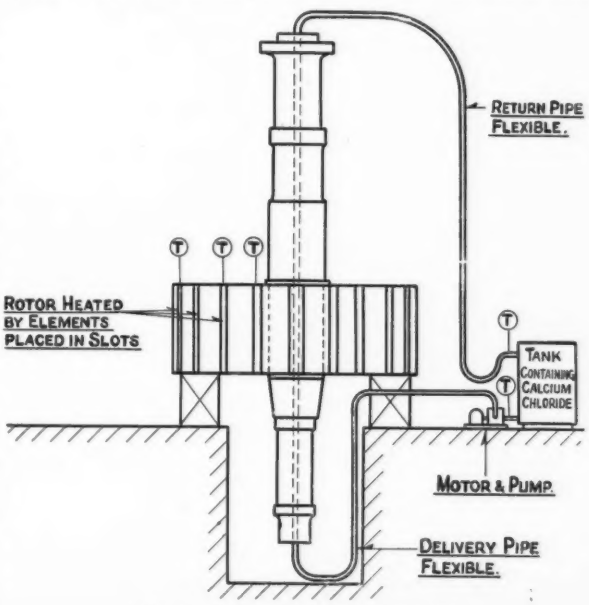

RETURN PIPE FLEXIBLE.
ROTOR HEATED BY ELEMENTS PLACED IN SLOTS
TANK CONTAINING CALCIUM CHLORIDE
MOTOR & PUMP.
DELIVERY PIPE FLEXIBLE.

Fig. 3.—Arrangement for cooling shaft.

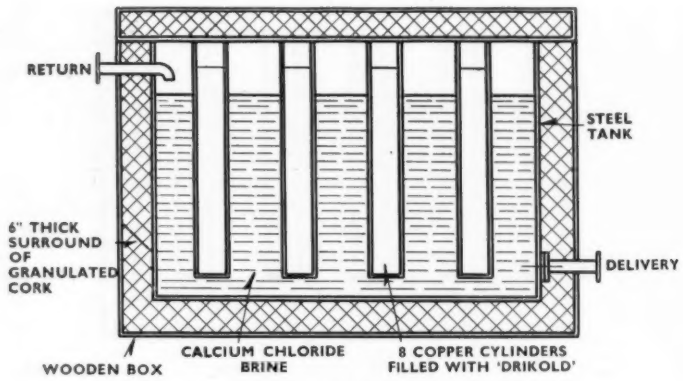


Fig. 4.—Cooling tank for calcium chloride brine.

by a special motor-driven pump of 60 g.p.m. capacity, flexible pipes being used so that the shaft could be withdrawn without breaking the connections.

The experiment with the dummy shaft was commenced at 9 a.m., heat being applied to the circumference of the rotor packet by means of electric elements in the dovetail slots. The chart in Fig. 5 gives the temperatures hour by hour obtained by thermo-couples in four positions, the temperature of the ingoing brine, the times when CO_2 was added and the amount. The brine circulating pump was started up at the same time as the heating elements were switched on, and the CO_2 was added to the brine at 4 p.m.

After the first four additions of CO_2 the rise in brine temperature was checked and continued stable at about 35° C. until 6 p.m., when it was decided to reduce the quantity of brine in the tank in order to quicken the action of the CO_2. Although 175 lb. of CO_2 was added there was a slight rise in temperature at No. 1 thermo-couple. At 8 p.m. the brine temperature was down to 3° C., so it was decided to attempt to lift out the shaft. The heat was switched off and during the fixing of the crane hook a slight drop in temperature occurred at points 2 and 4 on the rotor, as will be noticed on the chart in Fig. 5. The attempt was unsuccessful and it became essential to intensify the cooling and continue the heating. After adding 925 lb. of CO_2 within one hour, the brine temperature dropped to minus 21.5° C. and a further attempt was made to lift out the shaft, but without success. The heat was again put on, the pump kept running and tension maintained on the shaft by the crane. Just after 9.30 p.m. the shaft lifted 1 in., due solely to the force exerted by the crane, and was then removed without a scratch. It will be noted from the chart that the maximum temperature reached at the outside of the rotor was 206° C. and the thermo-couple on the outside of the shaft gave a reading at the time of extraction of 22° C., which was lower than the calculated temperature required at the inside of the shaft.

Using the data obtained from this experiment, the operation of removing the shafts from the two generator rotors was successfully carried out. In order, however, to obtain the same cooling conditions inside the actual shafts, special expanding glands were made to confine the brine to the portion of the shaft over which the rotor body is fitted. Fig. 6 shows the construction of the gland which was placed in position inside the shaft and then expanded by tightening the nut with a special spanner.

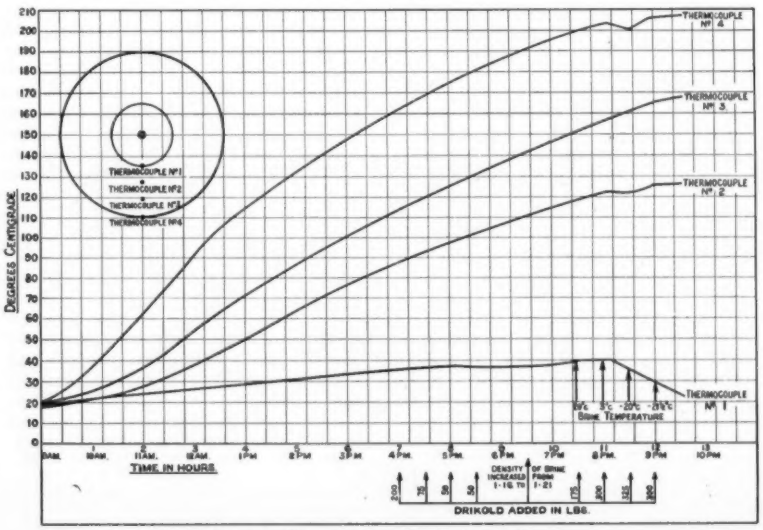


Fig. 5.—Temperature chart of experiment.

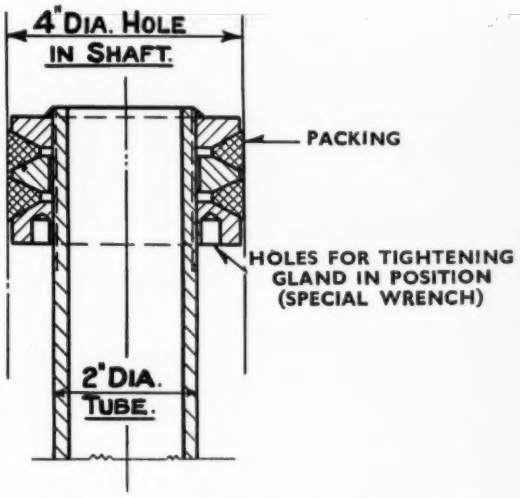


Fig. 6.—Gland used to localise cooling brine in shaft.

Fig. 7 shows one of the shafts being withdrawn, with the heating elements round the rotor and the cooling tank behind. An interesting point worth recording is that when the first shaft was lifted out, it had to be lowered again into position in order to shorten the crane slings. This operation occupied about 15 minutes but even after being back in position for this period the shaft was again lifted out without a mark on its surface.

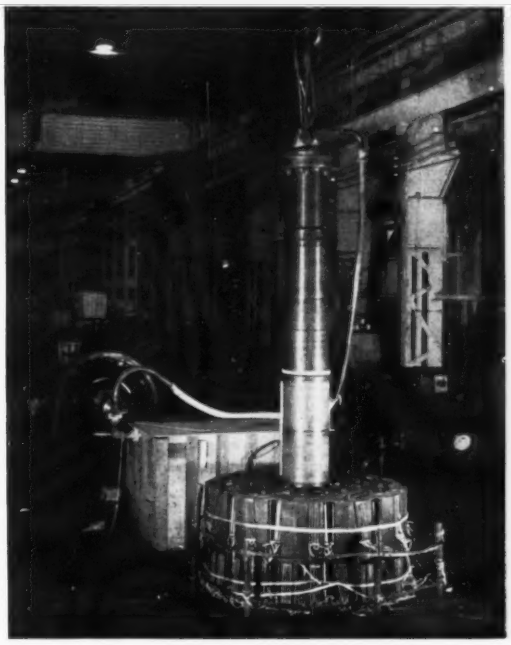


Fig. 7.—Withdrawal of rotor shaft.

Electricity and the Brick Making Industry.

The National Housing Drive has focussed the attention of everyone on the urgent need for building materials. It is therefore of special interest to electrical engineers to see how electrical plant assists the production of bricks, which still remain one of the fundamental materials used in building work.

The soil in the Bedfordshire area is richer in clay than anywhere in the United Kingdom, and there are many brickfields in Bedfordshire and its adjoining counties. The Marston Valley Brick Co.'s works at Ridgmont (Fig. 1) are an example of modern individual technique applied to one of the oldest industries in the world. By the use of electricity every sort of modernisation has been possible, and it would seem that there remain few aspects of the brick-making process which can be more efficient than those employed at Ridgmont Works. All the electric motors referred to in this article were supplied by The English Electric Company.

The Haulage Ways.

Clay from the excavating machinery is brought into the brickworks by one or more haulage ways, of railway line layout, in which the motive power is transmitted by steel cables. A hundred loaded trucks enter the works each hour, each truck carrying 2½ tons of clay. Fig. 2 gives a general view of the haulage ways.

Fig. 3 shows a 75 h.p. motor, of the louvre-ventilated type, driving one of the two main haulage ways employed at Ridgmont. Two reduction gears permit the motor speed of 727 r.p.m. to be reduced to a driving speed equivalent to 4 miles an hour on the road way. A full

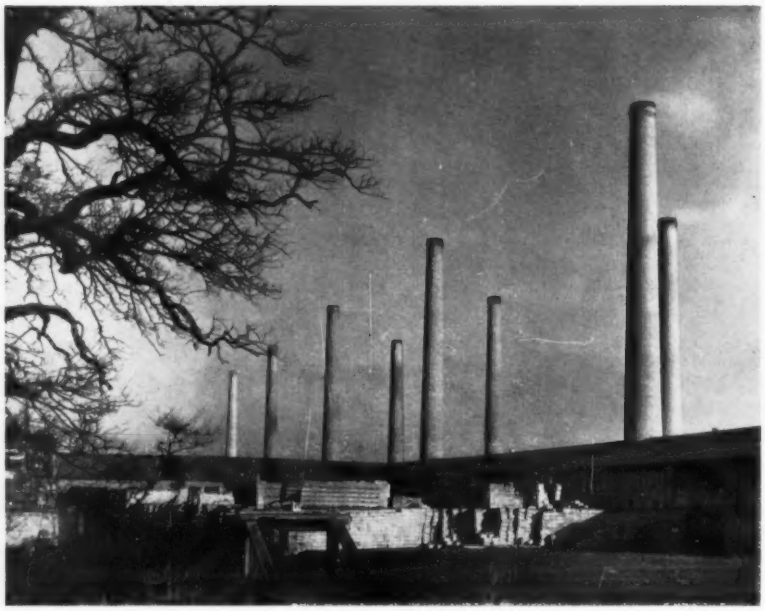


Fig. 1.—The Ridgmont Works of the Marston Valley Brick Company.

system of safety precautions is in operation, with bells and telephone stations so arranged that the remote starting gear of the haulage motor is not operated until the track is clear of personnel.

Grinding and Screening.

The brickworks are arranged in long, steel-framed, brick built bays, and the clay is brought by the haulage way to the top storey, which is about 75 ft. from the ground. Here the wagons are automatically tipped into hoppers, which lead to the ground floor where there is a battery of steel grinding wheels, driven by 50 h.p. motors, also of the louvre-ventilated type. Clay is fed to the grinders by a moving steel platform, driven by a 3 h.p. totally-enclosed motor. Fig. 4 shows the grinding wheels in operation. The starter of the grinder motor has a relay device which, when the load on the motor is reduced as the grinder empties, starts up the feeder motor, causing fresh clay to be precipitated into the grinder pans.

In the pans, the clay is ground into a fine uniform mass of a grey-green colour and of the consistency of oatmeal. The bucket-type conveyor carries the ground clay to the top floor, and here it is thrown into horizontal revolving screens of fine mesh. These are equipped with revolving bristle brushes on the outside which prevent the accumulation of sticky clay in the holes of the screen.

The clay is here further reduced until it becomes of the consistency of ordinary domestic sugar, and any particles which do not go through the small holes in the screen fall from the end of the revolving container back into the grinders, through vertical shafts arranged for this purpose.

The bucket-conveyor and the revolving screens are driven, unit by unit, by 10 h.p. motors, louvre ventilated. Near the screens is an "English Electric" combination fuse-switch distribution board.

Ground Clay Distribution.

In its path from the clay bed to the finished brick, the finely ground clay next passes on to a series of steel moving bands which distribute it to the various presses. Some of these bands are 24 in. wide and others 16 in. wide. They are of finely tempered steel to permit the utmost flexibility as they move over the rollers. At intervals along the bands are prongs, pointing

Fig. 2.—General view of haulage ways which bring the clay into the works.

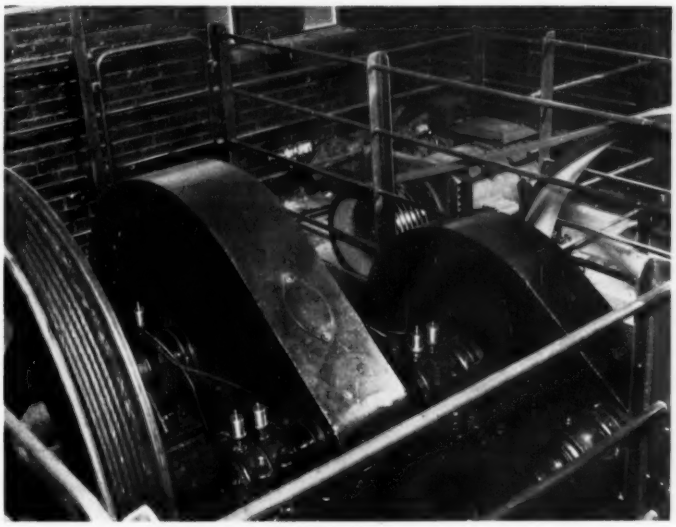


Fig. 3.—75 H.P. Louvre-ventilated type motor driving one of the haulage ways.

downwards, which stir the clay and prevent it settling into lumps.

At suitable points there are cross bands, where " ploughs " are arranged to divert more or less clay from the main band. These feeder lines, which are below the main conveyor, are driven by 20 h.p. motors. Fig. 5 shows one of these junctions, with the driving motor and associated gear.

The Presses.

The clay is now very nearly ready for the brick stage, and on the ground floor below the bands are situated a number of steel carriages, each containing two brick presses. These carriages can move along until they are opposite the chambers in which the bricks are to be burned. The chambers—arranged every few yards along the row—are used in rotation. When the carriages containing the twin presses are opposite the appropriate chambers, then immediately above them the ploughs are placed in position to throw off the clay from the moving bands. As there are a number of presses in operation at the same time, the ploughs can be adjusted so that exactly the right amount of clay is sent into the hoppers to keep the presses smoothly running.

The pairs of presses are driven by 10 h.p. motors, while a 5 h.p. motor of the totally-enclosed type is used to traverse the carriage along rails laid parallel to the mouths of the chambers. The presses are seen in Fig. 6.

Each press produces bricks at the rate of 22 per minute. The dies have special heating elements incorporated to prevent the clay sticking, and are made to produce bricks of all the well-known patterns—the plain Fletton, the Rustic, the Bullnose design, and many other varieties.

Baking the Bricks.

From the presses the bricks—which are still soft, and of a dark green colour—are loaded straight into the chambers, each of which is of a semi-circular brick built design, and holds 33,000 bricks in one charge. The bricks are burned for some 10 days at a temperature of approximately 1,040° C. The heat is transmitted to the bricks by hot air, entering through vents in the sides and roof of the chamber. Coal is the medium for providing the heat of the furnaces, which are above the chambers, and the tall chimneys—so familiar a sight in brick works country—give the necessary draught. After the first charge of hard coal, the cheapest type of slack is employed.

Fig. 4.—50 H.P. motor driving one of the clay grinding pans.

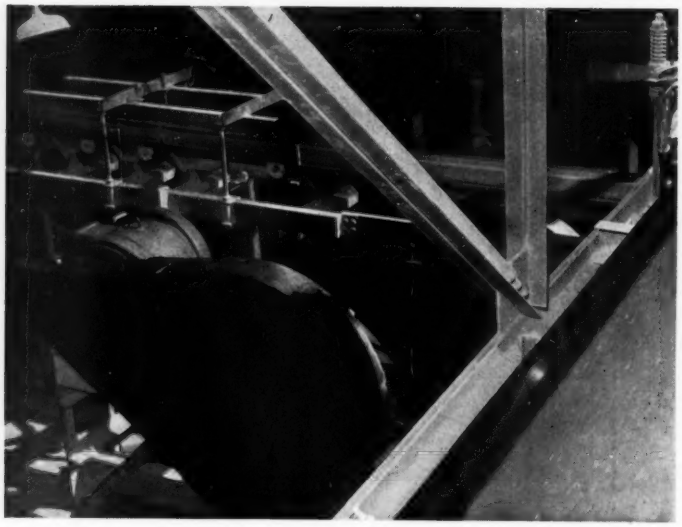


Fig. 5.—20 H.P. motor driving the steel bands which distribute the clay in the factory.

When the bricks have completed their burning, and have assumed the reddish-brown colour characteristic of the ordinary brick used in building, they are moved through the far end of the chamber, which is re-opened, straight out on to the loading bay, ready for rail transport or for taking away in heavy road vehicles.

The Electrical Equipment.

The electrical equipment of a brick factory is, as we have seen above, of vital importance to the whole process, and the Marston Valley Brick Co. have designed, in collaboration with the Bedford Corporation Electricity Department, substation equipment which takes adequate care of the various requirements, and ensures safety of supply under all conditions.

Power is received from the Bedford Corporation's 11,000-volt mains, and is led into the factory by cables terminating on a 4-panel 150 MVA. type "OLC" metalclad, oil-break, draw-out switchboard in a modern switchroom for high-voltage gear only, with adequate room for extension, and with cable troughs to permit fresh feeders being brought in. The switchgear is arranged for local control, and employs direct-operated overload relays. This is shown in Fig. 7.

From the high-voltage switchroom, cables lead to four indoor type 400 kVA., 11,000/400 volt transformers, each mounted in its own enclosure with brick separating walls and steel outer doors. A generous size of cubicle permits ventilation and air circulation, as seen in Fig. 8.

Cables lead the 400-volt 4-wire circuits to a low-voltage distribution board, situated in another specially designed room, again with facilities for extending the switchboard as required. No other plant is contained in this room. A general view is seen in Fig. 9.

This switchboard is composed of oil circuit-breakers and combination fuse-switch units connected to 3-phase 4-wire, air-insulated, metalclad, 600 amp. busbars.

The circuit-breakers are used for the transformer circuits (600 amp.), the bus-section switches (600 amp.), and the largest outgoing feeders to the factory—those to the presses—(200 amp.); while the combination fuse-switch units control the remaining factory feeders, the largest of which is rated at 150 amps., these feeding the grinding pans and the haulage gear.

Overcurrent and earth leakage protection is provided on the high-voltage side of the works transformers, with overcurrent protection on the low-voltage side.

Fig. 6.—One of the presses in which the bricks are made.

Fig. 7.—The 11 kV. switchroom showing the four-panel type OLC circuit breakers.

The press track feeders have overcurrent and earth leakage protection on the 400-volt circuit-breakers, and all the other factory feeders are protected by high rupturing capacity cartridge fuses.

Metering is carried out at the Corporation's

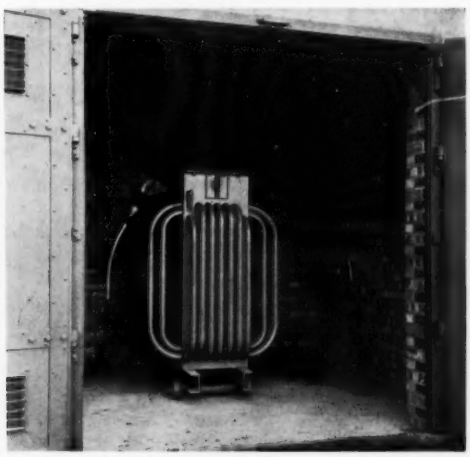


Fig. 8.—400 kVA., 11,000/400-volt indoor-type transformer.

11 kV. substation from which the supply is obtained.

The whole of the substation plant described has been supplied by The English Electric Company.

Auxiliary Services.

As well as controlling the power for the main brick-making process, the low-voltage switchboard has circuits for lighting, and small tools in the workshops and brick-making sheds. These are operated at 110 volts, by means of a step-down transformer.

There is also on the Company's premises an excellent canteen from which the majority of the workers obtain their meals. This is equipped throughout with "English Electric" heavy duty cooking equipment, including vegetable boilers, roasting ovens, fish fryers, steaming ovens, a large double range, two hot cupboards and two 20-gallon water heaters. A general view is seen in Fig. 10. There is also a refrigerator, not of "English Electric" manufacture, but supplied by the Company.

Brickworks engineers speak with enthusiasm of the reliability and flexibility of modern electrical equipment, which enables an extremely efficient production of bricks to be attained at such factories as the Marston Valley Brick Company's Ridgmont and Lidlington Works, where it is possible to produce, at one of these units, a million bricks per day and night shift.

We are indebted to Col. R. T. L. Shorrock, O.B.E., A.M.I.Mech.E., a Director of the Company; Mr. Miller, the Works Manager; and the Electrical Manager, Capt. S. Goodman, for their courtesy in permitting photographs to be taken at the Ridgmont Works.

Fig. 9.—Low-voltage distribution board comprising combination fuse-switch units and type SX oil-circuit breakers.

Fig. 10.—All-electric canteen kitchen equipped throughout with "English Electric" heavy-duty cooking equipment.

Underground Rectifier Substations for 11,000 Volt Supply.

By M. LLOYD JONES, A.M.I.E.Aust., of The English Electric Company, Sydney.

This article, which is reprinted from the Australian Journal, Chemical Engineering and Mining Review, *by kind permission of the Tait Publishing Co. Pty., Ltd., and the Wallarah Coal Co., Ltd., will be of interest to mining engineers both at home and overseas in showing how one mining concern has dealt satisfactorily with the problem of a gradually moving load centre—a problem which is of ever present concern wherever mining or quarrying takes place. By the installation of excess transformer capacity at the Nord Substation now, and later by transferring one of the rectifiers from the South West Slants Substation, followed subsequently by the interchange of both transformers and rectifiers at the two substations, provision has been made for the long-term condition on a truly economic basis. The suitability of pumpless air-cooled rectifiers for mining duties has been amply demonstrated by the many installations now in service using "English Electric" equipment. These include equipments supplied for underground haulage and other services in the gold mines of South Africa, copper mines in Rhodesia, coal mines in Australia and Chile, and for surface installation at collieries in India and in Great Britain.*

At its Catherine Hill Bay (N.S.W.) colliery, the Wallarah Coal Co., Ltd., uses a large number of direct current motors driving coal cutters, loaders, haulages, pumps, etc. Power for these motors is supplied at 250 volts D.C. from three "English Electric" and "Siemens" generators coupled to non-condensing, vertical, high-speed steam engines, located in a power house at one of the tunnel mouths. During the past 10 years the underground load centre has gradually moved to a point at a distance of over one mile from this tunnel mouth and future mining will take place mainly one and a half miles and more from the power station.

Total underground load of 1,200 to 1,400 amperes necessitated very heavy copper conductors, and future needs, using the same generating method, would have required an even greater cross sectional area of copper.

Fig. 1.—General view of the Wallarah Power Station showing the new 11 kV. Distribution and Metering Sub-Station in the centre foreground behind the two poles carrying the 11 kV. Overhead Feeders to the two Boreholes.

To provide the necessary D.C. voltage at the working face, it was found necessary to generate at 300 volts to compensate for the voltage drop in the cables. Heavy fluctuations of the load resulted in correspondingly severe voltage fluctuations in the mine causing unsatisfactory operation of the various motors, very variable lighting conditions and high maintenance on the machines, due to the heavy current drawn in order to provide the rated output, at a reduction in the voltage.

Remodelled Distribution.

Co-operation between the Wallarah Coal Co., Ltd., Newcastle Electric Supply Dept., Siemens (Aust.) Pty., Ltd., and The English Electric Co., Ltd., enabled the adoption of a scheme involving supply at 11,000 volts 3 phase 50 cycles. Power is fed, at this voltage, to two underground sub-stations equipped with 250 volts D.C. multiple-cubicle type, pumpless steel tank mercury arc rectifiers. These sub-stations are located at the present and future load centres and a diagrammatic representation of the scheme is shown in Fig. 2.

Surface Sub-Station.

The Newcastle Electric Supply Dept. brought in an 11 kV. overhead transmission line to a main distribution and metering sub-station at the tunnel mouth adjacent to the existing D.C. power station. At this point two 100 MVA. rupturing capacity, 11,000 volt draw-out truck cubicle type oil circuit-breaker equipments and one metering

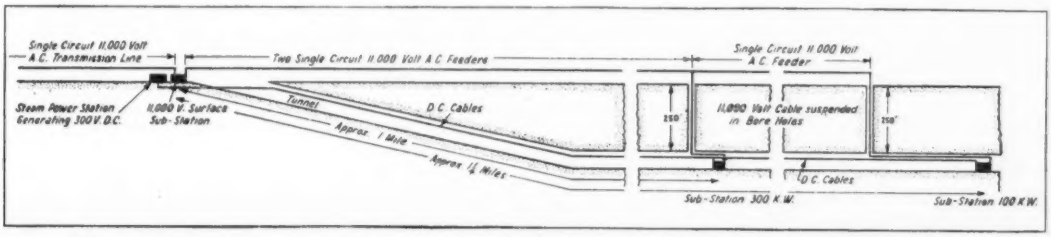


Fig. 2.—Diagrammatic Representation of Scheme shlowing location of d.c. Power Plant and Underground a.c. Sub-Stations.

TABLE 1—RELAY SETTINGS.

	South West Slants Sub-station (300 kW.).		Nord Sub-station (100 kW.).	
Current Transformer Ratio ...		15/5		15/5
	Percentage load setting	Time setting	Percentage load setting	Time setting
Over-current relays	175	0.5	50	0.8
Earth leakage setting	10	0.05	10	.05
Instantaneous over-current setting	200	—	150	—

cubicle were installed. Each rectifier control oil circuit-breaker is provided with an ammeter with transfer switch, double-pole inverse time limit over-current, and single-pole inverse time limit earth leakage induction pattern relays, single-pole instantaneous over-current attracted armature type relays, and shunt tripping fed by an alkaline battery charged at a low rate from the existing D.C. supply.

Leakage protection is in accordance with the requirements of the Department of Mines and covers the A.C. system to the rectifier transformers. The instantaneous trip is provided for protection against short circuits and rectifier arc back. Initial settings as given in Table 1 have proved satisfactory.

Metering equipment is of a type adopted as standard by the Newcastle Electric Supply Dept., for large consumers. The sub-station switchgear is illustrated in Fig. 3.

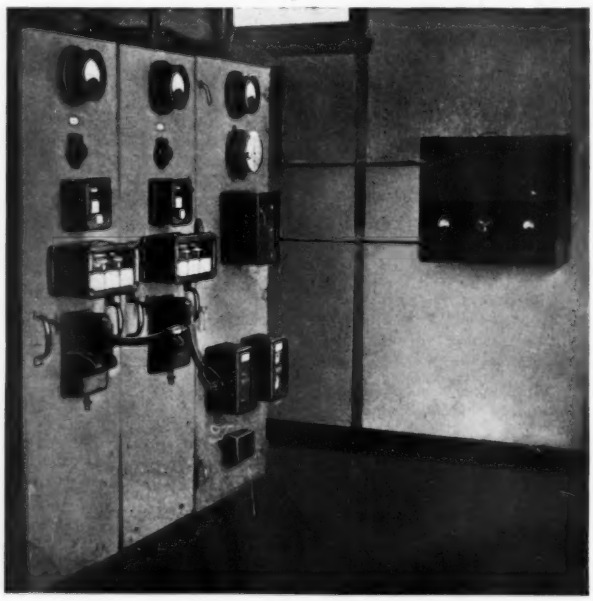


Fig. 3.—Interior view of 11 kV. Surface Sub-Station.

RECTIFIER FEEDERS.

Connection between the surface sub-station and the two underground sub-stations is carried out by means of two single-circuit overhead lines. These lines are adjacent for some distance and then divert to their respective bore holes. From the ends of the overhead lines and supported by bucket suspenders (Figs. 4 and 5), non-bleeding single-wire armoured, paper-insulated, 3-core, lead-covered cables convey power to the two sub-stations underground. Each bore hole is approximately 250 ft. deep, 8 in. in diameter and lined with steel bore casing. The length of run of cable at the sub-station ends was about 2,800 ft. at the South West Slants sub-station, and about 60 ft. at the Nord sub-station from the bottoms of the bore holes. Horizontal cable runs were supported near the roof by raw hide suspenders fixed to props approximately 6 ft. apart. Joints provided are of the lead sleeve in cast iron box type and are located on suitable shelves supported from the props as required.

SOUTH WEST SLANTS SUB-STATION.

This is adjacent to the present load centre and accommodates a 300 kW. mercury-arc rectifier transformer, oil immersed cubicle type non-automatic isolating switch, three 100 kW. 6-phase pumpless steel-bulb rectifiers of the "English Electric" type PVSO.720 and a D.C. switchboard. An interior view is shown in Fig. 6.

The isolating switch has a minimum making capacity of 50,000 kVA., but is normally to be used only for isolating the rectifier transformer.

The rectifier transformer is rated at 438 kVA. for 11,000 volts having a star connected 3-phase primary, double-star secondary with centre-tapped interphase reactor, and star connected 3-phase tertiary at 400 volts. The transformer is of the "ON" type and incorporates an 11-step manually-operated on-load tap changer to provide compensation in the event of A.C. voltage variations.

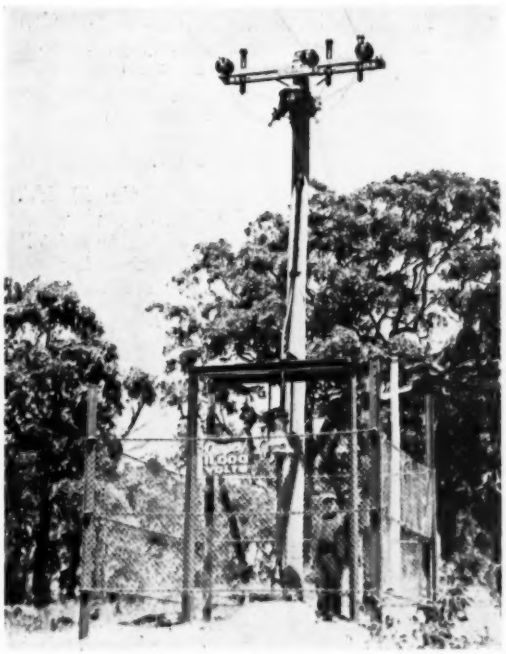


Fig. 4.—Borehole above South-West Slants Sub-Station.

Secondary voltage is arranged to provide a rectified D.C. voltage of 250 and the rectifier cubicles are arranged so that the transformer secondary feeds on to six busbars located over the top of the cubicles. From the busbars a connection is taken to the rectifier anodes through an anode choke and anode fuse. The anode chokes are provided to enable good paralleling between rectifier bulbs of slightly varying characteristics. The anode fuses provide high rupturing capacity high speed protection to the rectifiers in the event of short circuits or arc backs. The centre tap of the interphase reactor is connected directly to the negative terminal of the D.C. switchboard.

The tertiary of the transformer feeds into an ignition circuit on each cubicle which automatically causes each rectifier bulb to excite.

Method of excitation is shown in Figs. 7 and 7a. In effect a solenoid below the cathode pulls down a cylindrical plunger thus causing a jet of mercury to strike the ignition anode and draw an arc.

Each of the steel bulb rectifiers is cooled by a vertical-spindle fan driven by a squirrel cage motor connected to the tertiary of the rectifier transformer through a circuit breaker. Air at the rate of over 5,000 cu. ft. per min. is forced over the rectifier, and should the fan motor fail and the circuit breaker open, the main D.C. contactors will open, thus preventing the rectifiers from providing load when not receiving cooling air.

The cathode of each rectifier is connected through an ammeter shunt to the positive terminal on the D.C. switchboard.

The D.C. switchboard is arranged with one incoming board mounting two 1,500 amp. isolating switches, two 1,500 amp. contactors, contactor push buttons, control circuit fuses and switch, ammeter and ammeter shunt and voltmeter. Outgoing busbar from this panel feeds three similar distribution boards each fitted with one double-pole, double-throw 500 amp. isolating switch, two 400 amp. H.R.C. fuses, two 500 amp. contactors, contactor push buttons, control circuit fuses and switch and ammeter with shunt. In addition, indication of earth leakage is provided on the panel nearest the incoming panel by means of an ammeter and resistance to earth. Indication is obtained either positively or negatively by pressing the positive or negative push button.

Double-pole, double-throw isolators are provided to enable mine machinery to be run from the existing generating station in times of emergency.

Nord Sub-Station.

This sub-station is located some distance from the present load centre, but adjacent to a turbine

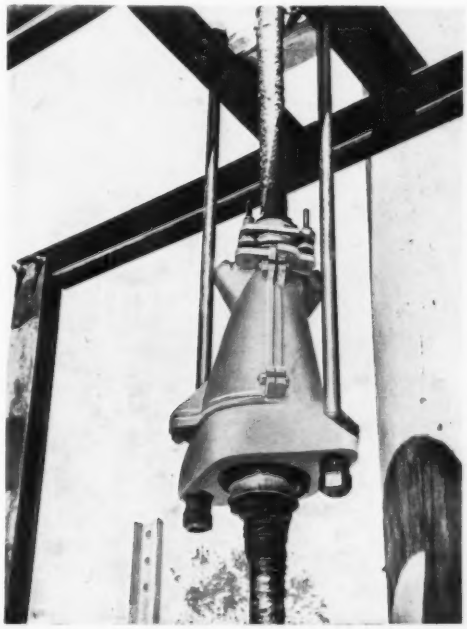


Fig. 5.—Close-up view of Siemens Bucket Suspender.

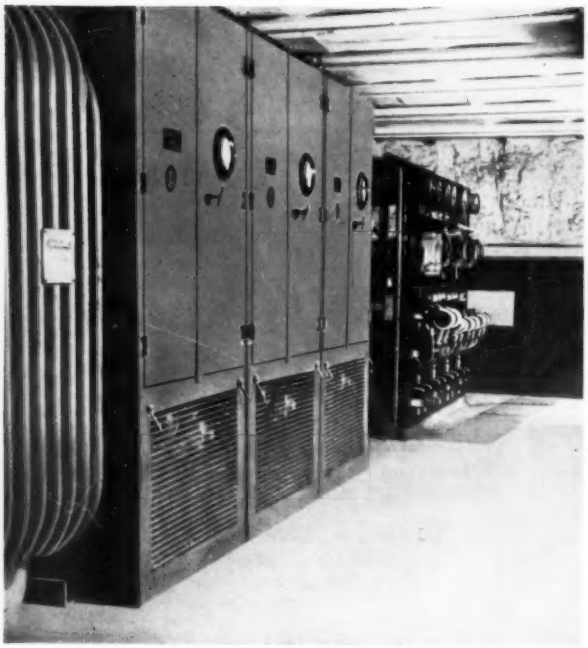


Fig. 6.—Interior of South-West Slants Rectifier Sub-Station.

pump which expels water accumulating in the mine through a bore hole to the surface, approximately 250 ft. above. The pump is motor-driven and requires approximately 350 amp. at 250 volts.

Lay-out of the sub-station is identical with that of the larger unit described, except that in this case a 200 kW. rectifier transformer is provided and only one 100 kW. "English Electric" rectifier cubicle is at present installed.

At a later date when the load centre changes, it is proposed to transfer one of the cubicles from the South West Slants sub-station to this site and immediately provide an output of 200 kW. At an even later date a further cubicle may be transferred and the transformers changed over.

Installation.

In order to ensure that the 11 kV. bore hole cable should not foul when being installed, it was decided to hoist it from the mine rather than feed it from the surface. In both cases this was completely successful.

In the case of the Nord sub-station, the rectifier transformer required to be hauled underground to site on a section of steel plate dragged along the skip rails.

Commissioning.

On commissioning, full-load tests were undertaken and four 44-gallon drums filled with water were provided to take the load per 100 kW. cubicle. This was satisfactory and by suitable arrangement of ventilation the steam was directed away from the sub-stations. Continuous make-up water was provided and a certain amount of difficulty was experienced with the mine water. This water was extremely acid and the plates were dipped barely an inch into the water in order to obtain full load.

Guarantee figures required that the rectifiers should provide 100 per cent. overload for 15 seconds and in each case this was achieved without difficulty.

Indications showed that there was little need to vary the manual tap changers on the transformers once a suitable setting had been obtained, as the voltage variation, at the sub-station, over

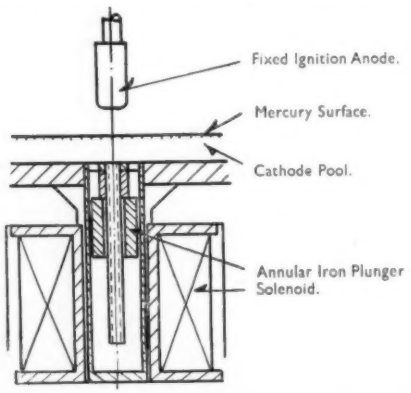


Fig. 7.

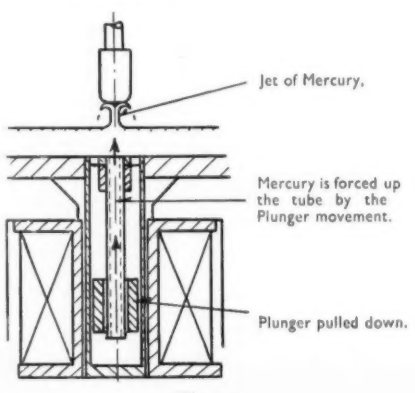


Fig. 7a.

Ignition system for pumpless steel-bulb rectifiers. Fig. 7 shows normal condition, and Fig. 7a at moment of ignition.

the load experienced was small.

As anticipated, the higher voltages provided to the machines enabled faster running with a reduction in the current drawn and a general improvement in the mine lighting, no appreciable variation being observed.

Reduction in the coal consumed to provide steam for non-condensing engines at the surface together with the removal of the heavy I^2R losses in the long D.C. cables from the surface and the improvement in the voltage at the machines will undoubtedly enable the production of coal at a reduced consumption of electric energy.

Equipment Supplied.

The contract for supply of the equipment was co-ordinated by The English Electric Co., Ltd., who provided the rectifier transformers and rectifier cubicles. Godfrey Pty., Ltd., acted as sub-contractors for the 11 kV. switchgear and Electric Control and Engineering Co., Ltd., for the D.C. switchboards. The H.R.C. fuses in the D.C. switchboard were supplied by The English Electric Co., Ltd., and Siemens-Elliott D.C. meters were fitted in the rectifier sub-stations. Supply of the bore hole cable was undertaken by Siemens (Australia) Pty., Ltd., who also supervised the installation of the cable.

The Napier "Naiad" Aero Engine.

This new engine has only recently been released from the Air Ministry's secret list and it is only permissible at present to publish the following general data.

The Napier "Naiad" aero engine, of which two views are shown in Figs. 1 and 2, is of the gas-turbine type designed for use in conjunction with a single-rotation, constant-speed propeller. Additional thrust is obtained from the exhaust gases.

The engine consists of an axial compressor, which delivers air to five combustion chambers into which fuel is sprayed. Combustion is a continuous process and the products are delivered to a turbine which drives the compressor and the propeller. The discharge is through a propelling nozzle in the form of a jet.

The propelling nozzle is provided where desired, to meet aircraft requirements, with a two-position control for orifice areas for (1) take-off and climb, and (2) level flight.

Starting is by means of an electric motor and igniter plug. A second igniter plug is arranged in reserve.

The air intake to the compressor is provided in the form of a hollow spinner on the propeller. The shanks of the propeller blades are enclosed by stream-line fairings.

The aircraft mounting ring is attached to the compressor casing and is positioned at approxi-

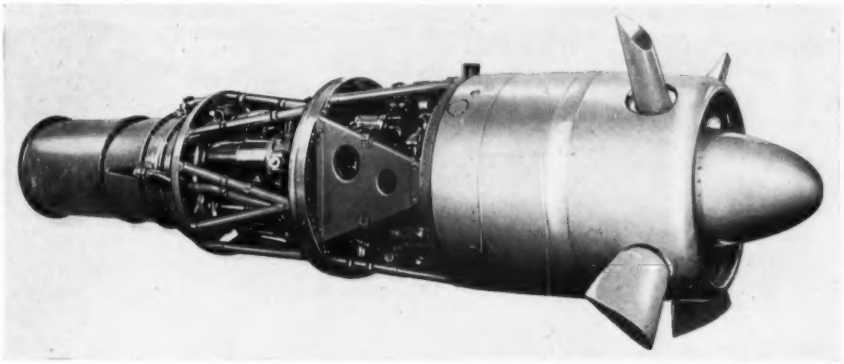


Fig. 1.—Napier "Naiad" aeroplane engine, from propeller end.

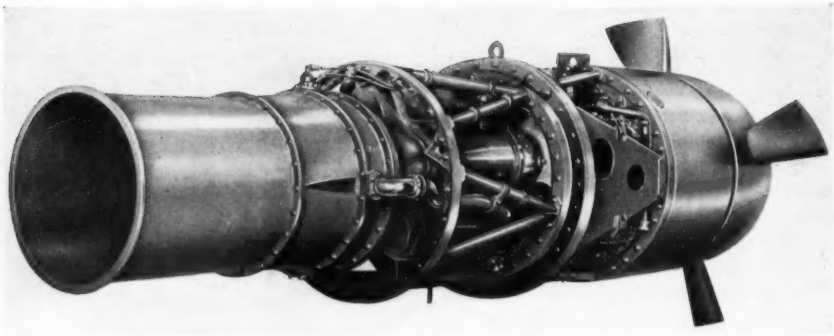


Fig. 2.—Napier "Naiad" aeroplane engine from jet end.

mately the mid-section of the engine.

The maximum diameter of the engine is 28 in. and its length from nose of spinner to turbine outlet flange is 8 ft. 6 in. Its weight is 1,095 lb. plus 2½ per cent. The direction of rotation is right-hand tractor.

The fuel used is aviation kerosene, to specification RDE/F/Ker.

The auxiliaries include a 24-volt electric starter, two fuel pumps, oil and metering pumps, an oil filter, propeller governor and braking control. A shaft of 50 H.P. transmission capacity is provided for driving an ancillary gearbox for aircraft accessories.

The following table gives the estimated performance at sea level (static conditions) :—

Condition.	R.P.M.	B.H.P.	Net jet thrust.	Total E.B.P.H.	Fuel (gals./hr.) consumption.
Max. "take-off" (I.C.A.N. atmosphere) ...	18,250	1,500	241	1,590	128.8
Max. "take-off" (Tropical atmosphere) ...	18,250	1,194	204	1,270	112.3
Max. cruising ...	17,000	902	268	1,005	96.2

Llynfi Power Station, South Wales

Record Construction Time and High Thermal Efficiency

In December, 1943, the first 30,000 kW. "English Electric" turbo-alternator set to be installed in the Llynfi Power Station of the South Wales Electric Power Company was put into service, only 19 months after turning the first sod on the site, and the second set went into service four months later; a record for the erection of a power station on a new site.

The official returns for 1946 of the fuel consumption and units generated at the power stations of Authorised Electricity Undertakings recently published by the Central Electricity Board show that Llynfi had the lowest average fuel consumption of 1.05 lb. of fuel per unit generated and the highest thermal efficiency of 26.17 per cent. of the 38 power stations in Group C with an output of between 200 and 500 million units a year. Only one power station, with an installed capacity of 300,000 kW. and generating over 1,000 million units a year, out of the total of 181 authorised undertakings in Great Britain, recorded better results.

In Group C, not only does Llynfi head the list for efficiency and coal consumption, but the 3rd, 4th and 5th places are also held by stations with "English Electric" generating plant.

The switchgear and transformers in Llynfi power station were also supplied by The English Electric Company.

The two "English Electric" 30,000 kW., 3,000 r.p.m. Turbo-alternator sets in the Llynfi Power Station of the South Wales Power Company.